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WHEAT SMUTS AND THEIR CONTROL

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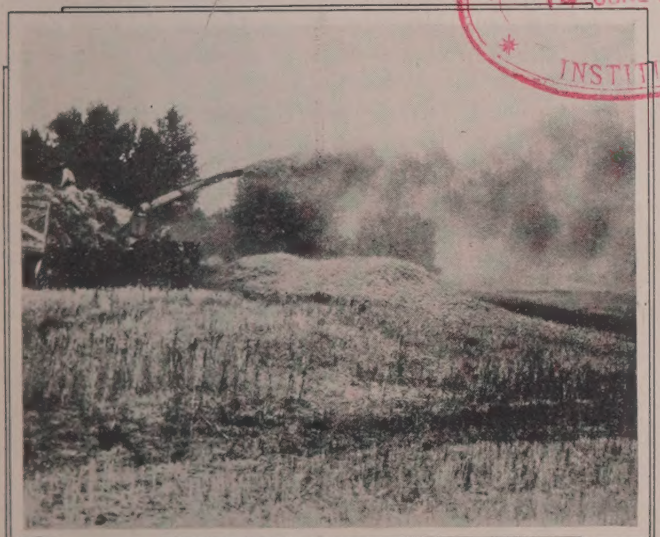

CLOUD OF SMUT SPORES FROM THRESHER

UNITED STATES DEPARTMENT OF AGRICULTURE

WHEAT is subject to three smut diseases. The purpose of this bulletin is to describe these diseases briefly, so that they may be identified by the grower, and to give recommendations for preventing them in subsequent crops.

All of the wheat smuts are seed-borne diseases. Two of them—flag smut and bunt or stinking smut—also may infest the soil. Insofar as the wheat smuts are seed-borne, they may be controlled by seed treatment. The spores of stinking smut and of flag smut carried on the surface of the seed can be killed by chemicals, such as formaldehyde solution and copper carbonate or other dusts.

Loose smut is carried inside the seed grain. It may be controlled by a hot-water treatment which raises the temperature of the wheat high enough to kill the smut but not enough to seriously injure the seed.

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WHEAT SMUTS AND THEIR CONTROL

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LOSSES FROM WHEAT SMUTS IN THE UNITED STATES

WHEAT in the United States is attacked by three smuts—stinking smut or bunt, loose smut, and flag smut. Stinking smut and loose smut are widely distributed in all wheat-growing areas in the United States, whereas flag smut is known to occur only in a limited territory.

Losses from wheat smuts are of two kinds—field losses, which result from reductions in yields, and discounts on the market because of the foul odor and discoloration of wheat affected with stinking smut.

Estimates made by the United States Department of Agriculture in cooperation with officials of various States show that smuts of wheat caused an estimated average annual reduction of 23,198,000 bushels in the wheat crop of the United States during a 19-year period. The estimated annual field losses from these smuts from 1917 to 1935, inclusive, are given in figure 1.

Stinking smut or bunt is responsible for about two-thirds of the field losses from wheat smuts, and the field damage is only a part of the loss it occasions. When stinking smut is present in wheat to any considerable extent, the foul, fishy odor given off by it permeates the entire mass of threshed grain, rendering it less desirable for flour making. The smut spores also blacken the grain more or less. The smut spores and the odor can be removed only by special cleaning and washing, the cost of which is reflected back to the growers through discounts or, in some sections, by a generally lower price for all wheat in the area. Discounts may run from 3 to 10 cents or even more a bushel. To losses in yield, therefore, must be added the market discounts on account of stinking smut or bunt, which may vary from $45 to $180 a carload, depending upon the amount of smut. The combined field and market losses in the United States, even at moderate wheat prices, amount to well over $15,000,000 annually.

[1] Died September 24, 1933.

The losses to the wheat farmer from stinking smut or bunt may be better appreciated if reference is made to the results of a survey made in one county in Nebraska, where detailed records were kept from 1926 to 1930. In this county alone, losses from stinking smut averaged $237,590 annually. In 1930 the losses on 1,000 farms in that county averaged $276.87 per farm, or considerably more than the average annual taxes per farm on the 1,117 farms in the same county. If such surveys were made in other wheat-growing areas, it is likely that similar losses would be found.

STINKING SMUT OR BUNT

DESCRIPTION

Stinking smut or bunt is caused by either of two species of fungi (*Tilletia tritici* or *T. levis*) which are so similar in their characteristics and action upon the wheat plant that they will be discussed together.

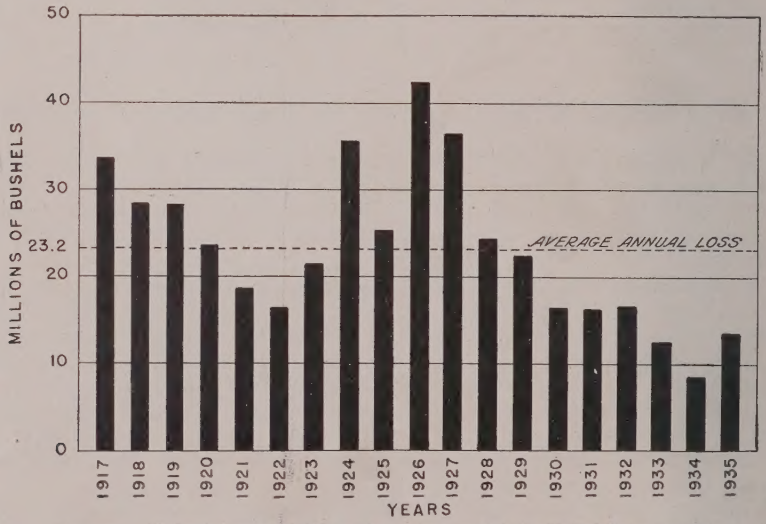

FIGURE 1.—Estimated annual field losses from wheat smuts in the United States, 1917–35.

At heading time the leaves of infected plants are a darker green color than the leaves of healthy plants, and, before ripening, the smutted heads also are slightly darker green than the healthy heads. When such smutted heads are examined closely they are found to contain bunt balls instead of grain, and the anthers usually are less conspicuous than those in the healthy heads (fig. 2). The bunt balls generally are shaped like the kernels, but often are shorter and thicker, especially when the wheat is ripe; this causes the glumes over them to spread apart more than is usual in healthy heads (figs. 2 and 3). Smutted plants are often stunted also.

When broken open, these smut balls are found to contain a mass of sooty black powder (fig. 4), the individual particles of which are the reproductive bodies or spores of the fungus. Many of these bunt balls are broken when the wheat is threshed, and the black powder is distributed over the healthy seed. If such contaminated grain is

FIGURE 2.—*A*, A sound head of bearded wheat; *B*, a bunted head.

sown without first being treated, particularly if the weather is rather cool after the seed is sown, the smut spores germinate at the same time that the wheat does, and the parasitic threads of the fungus enter the young wheat seedlings before they emerge from the soil. Once inside the young wheat seedling, the fungus keeps pace with the growth of the wheat plant and at heading time forms masses of foul-smelling spores in the heads where normal wheat kernels should be.

FIGURE 3.—Harvest Queen wheat: *A*, Sound head; *B* and *C*, bunted heads.

CONDITIONS INFLUENCING DEVELOPMENT

Experiments have shown that the stinking smut fungi can infect the young wheat seedlings much more readily when the soil is fairly cool after sowing, that is, when the soil temperature ranges from 45° to 55° F. Sowing wheat in a warm soil would be an effective method of reducing the percentage of bunt infection, but the warm soil is unfavorable for the best development of the wheat seedling and also encourages the development of certain other diseases. Early sowing of winter wheat also is favorable for hessian fly infestation in many localities. Therefore, in most sections it is not advisable to sow wheat early or while the soil is still warm.

FIGURE 4.—*A*, *Tilletia tritici* on Kanred wheat: *a*, Wheat grains; *b*, bunt balls; *c*, smut spores. *B*, *Tilletia laevis* on Harvest Queen wheat: *a*, Wheat grains; *b*, bunt balls; *c*, smut spores.

Smut control is but one factor in the production of a wheat crop, and other factors must be given due consideration in a smut-control program.

The free smut spores on the seed may be easily killed by a number of chemicals. Therefore, if the seed grain is properly treated with any one of these effective chemicals before it is sown, the spores on the surface of the kernels will be killed but not the wheat seed.

Sometimes the bunt balls are not broken during threshing, as they are protected by a tough outer layer. The chemical usually does not penetrate through this layer to the smut spores inside. When these bunt balls are later broken, as they often are in handling the grain or in the drill during sowing, they release live spores of the smut fungus, which may infect the young wheat plants. The unbroken bunt balls and partially smutted grains that are found in nearly all smutty wheat are especially troublesome in smutty durum wheat.

Soil infestation by bunt spores presents another difficulty in control. During the harvesting and threshing of smutty wheat the bunt balls become more or less broken, and the spores may be blown over the ground where winter wheat is to be sown in the fall, as is shown in the illustration on the cover page. In some localities, especially in the Pacific Northwest and the Intermountain States, where summer fallowing is almost universal, after the dry harvest season these spores may infest the soil to such an extent that the new crop will become infected, even though the smut spores on the seed have been killed by seed treatment. This soil infestation is most common in those wheat areas where the harvest season is very dry and where summer fallowing is practiced. Much of the wheat area where soil infestation is a serious problem is in isolated mountain valleys. It seems possible that the smut in these valleys is of local origin. If so, a concerted use by all farmers of varieties resistant to the local races of smut fungi and the adoption of a seed-treatment program may lead to practical elimination of stinking smut in these areas.

Where soil infestation occurs, no satisfactory control of bunt is known at present. Experiments are now under way to obtain a better knowledge of (1) the local seasonal influences upon infection, (2) the relation of heavily infected fields to the development of smut in the surrounding fields in the following crop, (3) the number and distribution of the physiologic races of smut fungi, and (4) the development of suitable varieties resistant to as many of these races as possible.

Fortunately, soil infestation is not likely to be a serious problem in the eastern winter wheat and spring wheat areas.

CONTROL METHODS

The most effective methods of controlling stinking smut are (1) the use of smut-free seed or of well-cleaned and treated seed from which the smut balls have been removed and (2) the use of varieties immune or highly resistant to the disease.

CLEANING AND TREATING THE SEED

Whether or not seed is smutty, good farm practice demands that it should be well cleaned, in order to remove not only smut balls but also weed seeds, light shriveled kernels, and other impurities. It is best

to select seed wheat that is as free from smut as possible. Very smutty wheat should not be used for seed because of the difficulty of removing all the bunt balls and killing all the spores on the seed.

To clean seed wheat, it should be put through a good fanning mill several times or until all the smut balls have been removed. The best results usually are obtained when the fanning mill is run at the prescribed speed, but at considerably less than its rated capacity.[2]

In many sections of the country there are now central seed-cleaning plants where, for a few cents per bushel, seed can be more thoroughly cleaned and the smut balls more effectively removed than is possible with the equipment found on the average farm. In a number of communities this work is being done very effectively by means of portable cleaning outfits mounted on trucks.

Several satisfactory seed treatments have been developed for the control of bunt where soil infestation does not occur. In general, these treatments fall into two classes: (1) Liquid treatments in which such materials as formaldehyde and copper sulphate (blue vitriol) solutions are used, and (2) dust treatments, in which copper carbonate, basic copper sulphate, organic mercury compounds, or other dusts are used.

Liquid Seed Treatments

The most commonly used liquid for controlling bunt is a formaldehyde solution made by thoroughly mixing 1 pint of commercial formaldehyde with 40 gallons of water. This should be sufficient for treating about 50 bushels of wheat. If the wheat is free from smut balls, coarse sacks may be half filled with the grain and immersed in the solution for 10 minutes. Care should be taken that every kernel of wheat is wet with the solution. At the end of 10 minutes the grain should be removed from the solution and allowed to drain. Enough seed may be treated the evening before sowing to supply the grain drill the following day.

When the smut balls cannot be completely removed from the seed the treatment should be applied in open tubs in order to float off the bunt balls. The seed can be poured slowly into the solution and stirred at the same time. Most of the smut balls will then come to the surface and should be skimmed off. After about 10 minutes the solution should be drained off through a screened hole at the bottom of the tub. If two such tubs are available the solution may be caught in the second tub, and another lot of seed can be soaking while the first lot is being drained and sacked. All sacks should be free from smut to avoid recontamination of the seed.

For treating large quantities of seed one of the commercial seed treaters may be used. These are built to float out the smut balls and wet the seed in a continuous process. Several precautions should be taken when formaldehyde solution is used: The solution should be of proper strength; the seed should be sown within 24 hours after being treated; the seedbed should be moist and the rate of seeding increased by about one-fourth to compensate for the swollen kernels. Formaldehyde treated seed sown in dry soil usually gives a very poor stand. When wheat is sown during a dry period the formaldehyde treatment should not be used.

[2] U. S. Department of Agriculture Circular 361, Removing Smut Balls from Seed Wheat.

Copper sulphate solution, prepared by dissolving 1 pound of the crystals and a pound of common salt in 5 gallons of water, may be used in the same manner as described for formaldehyde, except that the grain should be subsequently dipped in milk of lime and spread out to dry. The milk of lime is made by stirring 1 pound of quicklime in enough water to slake it and then increasing the liquid to 10 gallons. The reaction of the copper sulphate and the milk of lime results in a coating of basic copper sulphate on the seed. This treatment is more cumbersome and troublesome to apply than is formaldehyde and therefore is less widely used.

Dust Seed Treatments

Dust seed treatments have become more popular than liquid treatments for the following reasons: (1) If properly applied, they do not reduce the percentage of germination and frequently increase it; (2) the seed can be treated in advance of sowing and stored without injury; (3) dusted seed can be sown at any time either in dry or moist soil; (4) labor and expense of treating wheat for large acreages is reduced; and (5) treated grain is protected from weevils and to some extent from rodents.

Copper Carbonate Dusts

Basic copper carbonate has been the dust most widely used to control stinking smut during the last 15 years. Two types of this dust are on the market. High-grade or so-called pure copper carbonate contains about 50 percent of copper and should be applied at the rate of 2 ounces per bushel. The cheaper grade, known as diluted or extended copper carbonate and frequently sold under trade names, contains about 20 percent of copper and usually should be applied at the rate of 3 ounces per bushel. An excessive quantity of either type of dust will not injure the seed but may tend to clog the drill in humid weather.

Basic copper sulphate, such as is used for dusting fruit trees and truck crops, also is effective in controlling stinking smut. This dust contains about 50 percent of copper and should be applied at the rate of 2 ounces per bushel.

To be effective, the above-mentioned dusts must be thoroughly mixed with the seed, so as to obtain a thin film of the chemical over the entire seed. This is best done by means of a rotary machine made especially for that purpose. A number of such treating machines are on the market, but satisfactory oil-drum or barrel mixers may be made on the farm.

Oil-drum mixer

A 30-gallon oil drum is a convenient size (fig. 5). Cut out half of one head. Bolt to the top of the remaining half a board 1 inch thick, 6 inches wide, and the proper length to fit snugly against the inside rim of the oil drum. Let 1 inch of the cut edge of steel extend beyond the board. Cut a semicircular wooden head to fit the open half of the

drumhead and hinge this to the 6-inch strip. If necessary, nail a strip of an old automobile inner tube along the edge of the door to make it dusttight. Attach a hasp to hold the door tightly against the edge of the drum when closed.

The axle is made from ¾-inch pipe, 48 inches long, threaded at one end. It should pass diagonally through the drum, as shown in figure 5, and extend about 8 inches beyond each end. It is best to have the drum and axle welded together, but the axle may be bolted to the drum.

Nail or screw a mixing board, 1 inch thick by 6 inches wide, across the full inside width of the drum. Place the board edgewise and about two-thirds of the way back from the opening, as illustrated (three nails being shown in each end of the board). Mount the mixer on sawhorses.

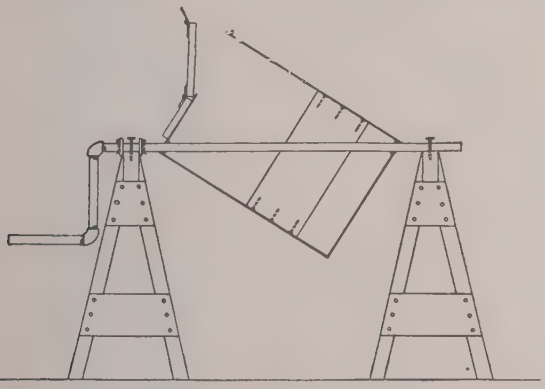

FIGURE 5.—An oil-drum mixer for treating seed with copper-carbonate dusts. (Designed by R. S. Kirby, Pennsylvania State College.)

BARREL MIXER

Use a tight 30- or 40-gallon barrel made to hold liquids. Mark out a door about 8 inches wide by 14 inches long across two wide staves (fig. 6). Fasten hinge and straps to staves before sawing out the door. Saw the staves on a slope toward the middle of the barrel to get bevel edges on the door. Line bevel edges with rubber from an old inner tube to make the door dusttight.

Insert a mixing board 1 inch thick and 9 inches wide along the full inside length of the barrel. Nail it to the ends of the barrel so that it lies edgewise against the inside of the barrel wall opposite the door, as illustrated.

On each end of the barrel screw or bolt a floor or railing flange threaded to hold 1-inch pipe. Insert a piece of 1-inch pipe 6 inches long in each flange to serve as an axle. Use 1- or ½-inch pipe for handles.

Mount the barrel on a boxlike stand, as shown in figure 6, or on sawhorses.

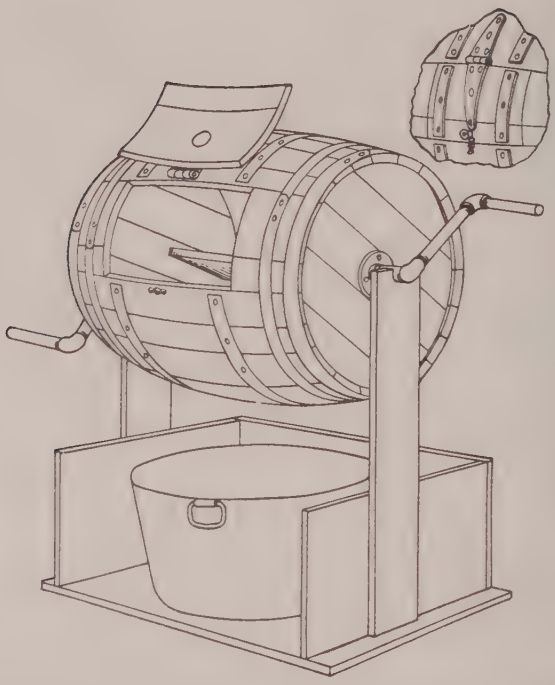

FIGURE 6.—A barrel mixer for treating seed wheat with copper-carbonate dusts. (Designed by F. W. Oldenberg, University of Maryland.)

CAUTION

Copper dusts are poisonous.

Wear a mask or a wet cloth or wet handkerchief over the nose and mouth when treating grain with copper dusts. The treating should be done in a well-ventilated place.

Copper carbonate and basic copper sulphate sift into all working parts of the drill. After the drill has stood overnight or longer, turn the feed shafts with a wrench to free the feed wheels. This avoids possible twisting of feed shafts and breaking of gears. Oil the gear bearings frequently.

Do not use or sell treated wheat for food or feeding purposes.

Do not mix copper dusts and wheat in the drill box or by shoveling over on the floor. Satisfactory control of smut is not obtained by these methods.

ORGANIC MERCURY DUSTS

In recent years certain organic mercury dusts have been found to control bunt very satisfactorily. The one now most widely used contains 5 percent of ethyl mercuric phosphate in talc.[3] It should be applied at the rate of only one-half ounce per bushel. It has several advantages over the copper dusts. It is slightly cheaper; it need not be mixed so thoroughly with the seed; and it does not clog or interfere with the action of the drill. Its disadvantage is that it may

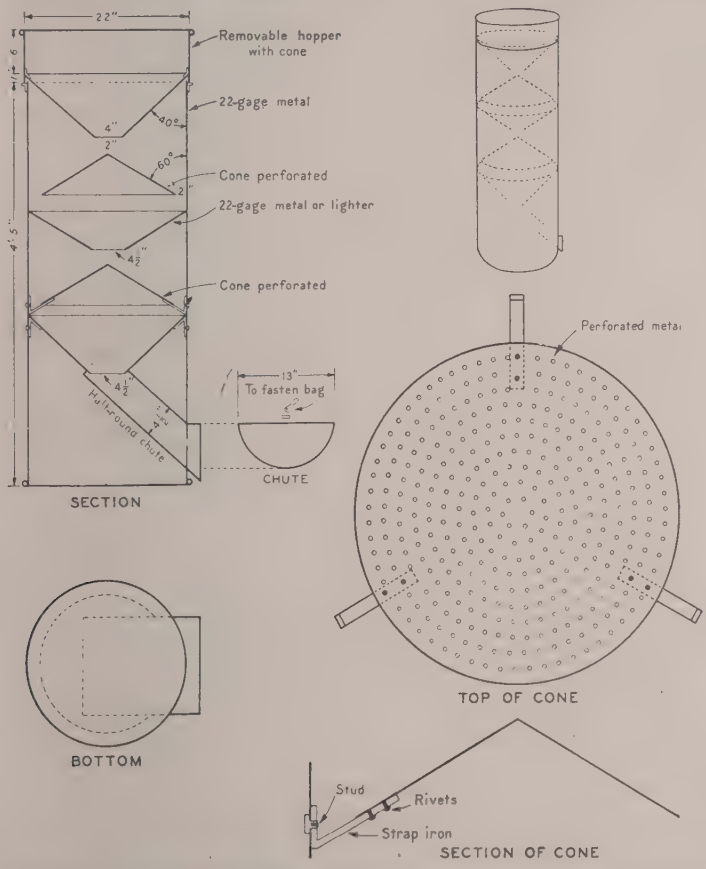

FIGURE 7.—A gravity seed treater for applying ethyl mercuric phosphate dust to seed wheat.

injure the seed if applied at much more than the prescribed rate of one-half ounce per bushel, or if the treated seed is stored improperly or for too long a time. The mixers used for applying the copper dusts also may be used for applying this dust. However, since such thorough mixing is not highly essential in the case of this organic mercury dust, it may be more easily and rapidly applied by means of a gravity mixer such as is illustrated in figure 7.[4] This mixer can be made by a

[3] This dust is marketed under the name of New Improved Ceresan.

[4] U. S. Department of Agriculture Circular 415, Equipment for Applying Dust Fungicides to Seed Grain.

local tinner from the specifications given. The treater may be mounted on the rear of a truck for convenience. To every bushel of seed as it is poured in at the top there is added one-half ounce of the ethyl mercuric phosphate dust. The dusted seed is bagged as it comes out at the bottom of the mixer and is ready for sowing the next day, or it may be allowed to stand for several weeks. There are now on the market several excellent treating machines for mechanically applying the proper amount of ethyl mercuric phosphate dust to the seed, thus eliminating the necessity of carefully measuring the dust and seed. While most of these machines are suitable only for large seed houses and other central cleaning and treating plants, there are a few that have been made for farm use.

The central cleaning plants, as well as the portable outfits previously mentioned, almost invariably are equipped also for treating seed. They are able to do this work more efficiently than is usually possible on the farm, and the use of these facilities by the farmers is increasing.

If no treater is available, ethyl mercuric phosphate dust may be applied to the seed fairly well by means of the shovel method. A bushel of seed is spread upon a clean grain-tight floor, and one-half ounce of the dust is scattered over it. As additional bushels of seed are added to the pile, each has scattered over it one-half ounce of the dust. The pile is then shoveled and reshoveled several times until streaks of dust in the grain are no longer visible. The grain is then left either in an uncovered pile or, preferably, in sacks for at least 24 hours before being sown.

CAUTION

Ethyl mercuric phosphate dust is poisonous.

Wear a dust mask or *dry* cloth over the nose and mouth when applying this dust to the grain, especially when using the shovel method.

Do not leave the dust on the skin, especially when perspiring, as it may cause blistering.

Treat the seed in a dry, well-ventilated place.

Store treated seed in a dry place.

Do not use or sell treated seed for food or feeding purposes.

RESISTANT VARIETIES

The breeding of varieties of wheat resistant to bunt or stinking smut is greatly complicated by the existence of different races of the bunt fungi. Some varieties generally considered resistant to bunt may be found susceptible when grown in certain localities. This is explained by the presence of different physiologic races or strains of the smut organism in some wheat-growing areas and not in others. Varieties of wheat are being developed which, it is hoped, will be resistant to all of the important races of the bunt fungi. Until this is done it is important to treat the seed of the supposedly resistant varieties, in order to prevent the increase of some virulent race or races

of the bunt fungi that in the beginning may be present in very small quantities, but which will increase from year to year.

If resistance to bunt were the only factor to be considered in developing a new variety the task would be much easier. However, to be commercially desirable, any new variety resistant to bunt must also have the other characters desirable for a good wheat in the locality where it is to be grown. It must be a good yielder, produce desirable milling grain, mature at the proper time, be resistant to other diseases, etc.

FIGURE 8.—Appearance of loose smut in wheat when the sound heads are in bloom.

LOOSE SMUT

DESCRIPTION

Loose smut of wheat, commonly known simply as "smut" or "blackhead," is different from stinking smut and flag smut. As soon as the wheat heads out, the smut is very noticeable (fig. 8). The diseased heads are almost completely destroyed by the smut. Instead of normal wheat, chaff, and flowers, black masses of smut, composed of spores of the smut fungus (*Ustilago tritici*), appear along the axis of the head. The spores are easily shaken from the smutted heads (fig. 9) and may be carried for long distances by wind, insects, or other agencies. The greatest distribution of loose smut spores takes place at about the time the healthy wheat is in bloom (fig. 8). Some of the spores may lodge in the flowers during the short period in which the glumes open in blooming. Here the spores germinate and develop infection threads that grow into the very young wheat kernel inside the chaff. When mature, infected kernels cannot be distinguished from smut-free kernels. However, if such wheat is used for seed without first being treated, the smut fungus inside the seed starts to grow as the kernel germinates, spreading upward into the tender tissues of the plant as it develops. Finally, when the wheat heads appear they are composed of masses of smut. Wheat is infected by the loose smut fungus only through

the flowers. The disease does not infect wheat through the seedlings, as do stinking smut and flag smut.

CONTROL METHODS

Because the loose smut fungus is carried inside the seed, it is necessary to apply a treatment that will penetrate the seed and kill the fungus. Surface disinfectants that control stinking smut and seed-borne flag smut will not control loose smut. The hot-water treatment only is effective. If the treatment is properly applied, the heat penetrates the seed and kills the dormant fungus without killing the wheat germ, because the wheat can withstand higher temperatures than can the smut fungus.

FIGURE 9.—Wheat heads infected with loose smut as they look after the smut spores have been shaken off and the sound heads have begun to fill.

There are two other possible methods of controlling loose smut: To grow resistant varieties of wheat; and, in arid climates where wheat is grown under irrigation, to withhold water during the blooming period.

HOT-WATER TREATMENT

Two different hot-water treatments have been devised, the modified hot-water treatment and the single-bath hot-water treatment. In the former the seed is presoaked for 4 hours in cold water, dipped in water at about 120° F. to warm the seed, and then soaked for 10 minutes in water at 129°. In the single-bath method the long presoaking in cold water is omitted and the seed is soaked for 1 hour and 50 minutes in water at 118.5° or for 1 hour and 35 minutes at 120°. In the 10-minute bath of the modified treatment, and throughout the single-

bath treatment, care should be taken to maintain closely the recommended temperatures.

In both the modified and single-bath treatments soaking causes the seed to swell considerably. The sacks used in treating the seed, therefore, should be only half filled and should be tied at the top. Only coarse sacks should be used. During the presoak period of the modified treatment and throughout the single-bath treatment the sacks should lie on their sides and should be turned or rolled occasionally to prevent caking of the swelling seed. Immediately after being treated, the seed should be raked out in a thin layer to cool and dry. It is safer to sow the seed after it has been thoroughly dried, but it will run freely through the drill as soon as it is surface dry, when it may be sown. In the latter case the drill should be set at a higher seeding rate to allow for the swollen condition of the grain. Seed that is only surface dry still contains enough moisture to cause germination in a dry soil. If sown in dry soil, some of the seedlings may die, and the stand may be severely injured.

The hot-water treatments are not recommended for treating seed for the entire crop, because they are difficult to apply and often cause injury to the seed, particularly when the seed coats have been broken in threshing or otherwise. If seed from smut-free fields cannot be obtained, it is best to treat only a sufficient quantity for sowing a seed plot, and the farther this plot is isolated from fields of untreated wheat the better the results will be. The crop grown on the isolated seed plot from treated seed and successive crops from the same seed lot may remain relatively free from smut, so that further seed treatment will not be necessary for a considerable period. However, reinfection of the seed in the seed plot may take place rapidly. The amount of smut in nearby fields and the influence of climatic factors on its spread and on its development in the wheat flower doubtless play an important part in this reinfection. If the seed wheat to be treated for loose smut also carries spores of stinking smut or bunt, the hot-water treatment will control both; but none of the treatments recommended for the control of stinking smut will control the loose smut.

In several States, community seed-treating plants for applying the modified hot-water treatment have been tried and found satisfactory. Usually they are managed by the county agricultural agent or by a group of neighborhood farmers. Through the use of treated seed and of seed from crops produced from the treated seed a number of large, relatively smut-free areas have been established. The beneficial effects of the treatment are made more lasting in this way, as the fields within the smut-free areas are mutually protected from infection by loose smut.

CONTROL UNDER IRRIGATION

Loose smut rarely is found in wheats grown on dry land in arid climates. Experiments have shown that low relative humidity of the atmosphere during the inoculation period, that is, when the sound wheat heads are in bloom, inhibits the germination of loose-smut spores, thus reducing or preventing infection. Therefore, in arid climates it should be possible to control loose smut in wheats grown

under irrigation by withholding water during the blooming period. Thus, the influence of the normally dry atmosphere in preventing infection would be given full play. Details for the practical application of this method of control have not been worked out.

RESISTANT VARIETIES

Wheat varieties differ widely in their resistance to loose smut. Many of the important varieties are susceptible. In view of the difficulty in controlling loose smut through seed treatment, reduction of loss through selecting and breeding resistant sorts would seem the logical course. This problem, however, is complicated by the existence of physiologic races in the loose smut fungus. The number and distribution of races in the United States and the resistance or susceptibility of wheat varieties to the different races has not been determined.

FLAG SMUT

Flag smut has long been prevalent in Australia, where it is one of the most destructive diseases of the wheat crop. Under some conditions this disease often destroys 10 percent of the crop, and losses of one-half of the crop are not rare. Flag smut also occurs in China, Japan, India, South Africa, Italy, and Spain.

In the United States, flag smut was discovered in Missouri in 1918. Later it was found in several counties of Illinois near St. Louis, Mo., and in several counties in Missouri and Kansas near Kansas City. Recent surveys indicate that the range of the disease is gradually increasing from these centers of infection.

DESCRIPTION

Flag smut appears as long black stripes running lengthwise on the leaf blades and on the upper parts of the stems of the plants, as shown in figure 10.

Infection in the field usually can be detected by short or more or less dwarfed stalks which seldom produce heads. Usually the entire plant is affected, although partly infected plants are not uncommon in certain varieties. When infected leaves dry, they split along the black streaks and free the black powdery spores of the smut fungus (*Urocystis tritici*). The spores fall to the ground, are blown to adjoining plants, and are spread by the feet of animals and man and by machinery. When infected wheat is being harvested, flag smut spores are carried to the wheat kernels of uninfected plants. This smut lives over in the soil, or, as is the case with bunt, it may be carried on contaminated wheat seed. Infection of the young wheat seedlings takes place during germination. After entering the seedling, the fungus remains inside the plant, but infected plants can be detected by the black streaks on the leaves before the jointing of the plant begins.

CONTROL METHODS

Flag smut of wheat can be controlled by quarantine and sanitation, seed treatment, and the growing of resistant varieties.

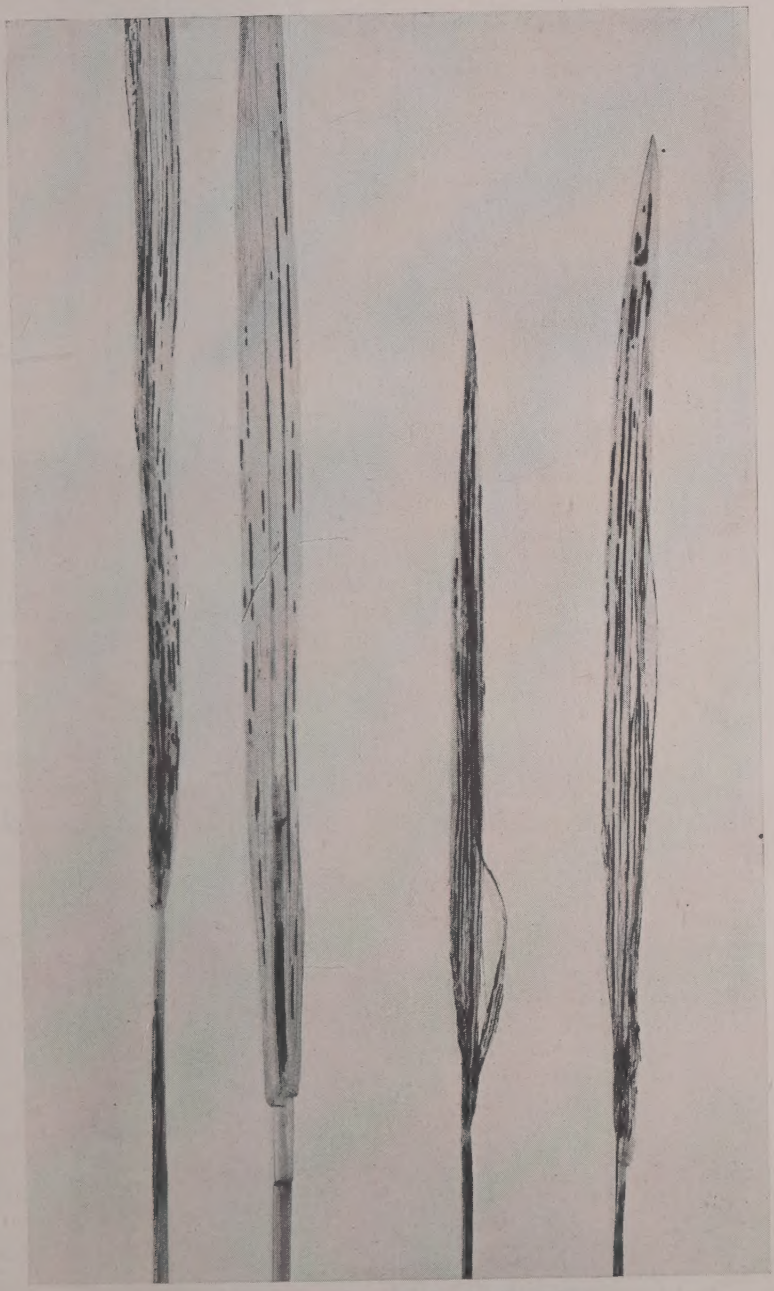

FIGURE 10.—Flag smut in leaves and stalks of wheat.

QUARANTINE AND SANITATION

Since flag smut is not generally distributed throughout the United States, any material, such as straw, manure, etc., that contains flag smut spores may serve as a source of infection and should not be carried to uninfested areas. If such material is to be returned to the land, it should not be applied to fields where wheat is to be sown. Great care should be taken to prevent the introduction of flag smut into States where it does not already exist.

SEED TREATMENT

Seed treatments, such as those recommended for stinking smut or bunt, will effectively kill the spores of flag smut that are carried on the seed but will not affect the spores in the soil.

RESISTANT VARIETIES

The use of resistant varieties of wheat promises to be the most satisfactory method of controlling this disease in infested areas. In experiments in which seed of a large number of wheat varieties was heavily dusted with spores of flag smut and sown in infested soil, the plants of many varieties were free from the disease. The most promising resistant varieties commercially grown in the flag-smut areas are Shepherd, Trumbull, Gladden, and Fulhio. Varieties very susceptible to flag smut are Flint, Fultz, Harvest Queen, Jones Fife, and Red Wave. If these varieties are replaced in the flag-smut areas by the wheat varieties found to be resistant, no serious losses are likely to result.

SUMMARY OF SEED TREATMENTS

The recommended seed treatments for the control of the different smuts of wheat are summarized in table 1.

TABLE 1.—*Seed treatments for control of wheat smuts*

Kind of smut	Disinfectant	Quantity, strength, or temperature	Duration of treatment
Stinking and flag	Copper carbonate dust; basic copper sulphate dust.	2 to 3 ounces per bushel.	Mix thoroughly in tightly closed container until each kernel is coated with dust.
	Ethyl mercuric phosphate dust.	½ ounce per bushel	Mix as above; use gravity mixer or mix by shoveling over several times on a clean floor.
	Formaldehyde solution	1 pint to 40 gallons of water.	Soak 10 minutes; skim off smut balls.
Loose	Hot water (presoak or modified method).	129° F	Soak 4 to 6 hours in cold water, dip in water at about 120° F. for a moment, then soak 10 minutes at 129° F.
	Hot water (single-bath method).	120° F	Soak 1 hour and 35 minutes.

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